Establishing Polygon Accuracy

by sampling for "Within-Polygon Variability (WPV)" in the Vegetation Inventory of British Columbia

by:

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General Discussion

One of the typical questions which is asked of any inventory is "How accurate is a specific polygon after adjustments are made and a final inventory database is available ?". This is an important question for harvest planning, and for timing silvicultural treatments where a specific polygon is grown, treated and harvested. Users are quite rightly concerned about the accuracy of individual polygons, not just the overall totals, and need an estimate of this difference. The set of differences is probably best described by 2-dimensional graphs or by histograms, but a single percentage error can also be stated from the results of this project.

It is therefore desirable for the MoF Resource Inventory group to provide users with some indication of the accuracy of these individual polygons. For discussion, let us assume that the overall accuracy of the BC inventory is quite good (say ±2%). The user may know that each polygon is not that accurate, but they will have no idea what difference is reasonable unless they are specifically informed. If they are told that any small-scale field check they might install is likely to be ±40% from the stated values (and that this is mostly due to their sample, not the actual situation), then a specific difference of -30% in a polygon will not surprise them.

To hear that when it appears to be ±40%, that it is likely to be off by only about ±14% should please them even more. If no expectation is stated, typical apparent differences will cause the user to feel that the ±2% figure is not realistic, and reduce the credibility of the product. Although statisticians may remind people that "sampling errors" are for totals, the tendency to check individual polygons is powerful, and needs to be anticipated by the Resources Inventory Branch.

In the following discussion we will use stand volume as an example simply because it is easy to visualize, but the principles are the same with any measurement. While the overall error of inventory volume will be well known, there is normally no indication of the accuracy for individual polygons. In most cases, users of the data will only check on the accuracy of individual polygons, and often by a biased and small sample, but their impression of the inventory accuracy is formed by these comparisons.

At some point, the inventory process needs to answer this question :

If I check the volume of an individual polygon in this inventory, what difference should I expect to find ?

There are some indirect ways to try to compute this value, but they depend on assumptions that are not always reasonable and on statistical arguments which most people simply would not understand, even with some effort. It is far better to have a direct check on the accuracy which people can understand and interpret. In addition, the data from such a direct check is of considerable technical interest for other purposes. The process of carrying out this direct check is developed in this report.

Cause of the problem

Inside a typical forest polygon the variability can typically be on the order of 80% or more. Therefore, a single plot which is put in to check "the accuracy" will show an "artificial difference" of this magnitude *even if the polygon volume was exactly correct*. Putting in only a few plots is precisely what we can expect people to do when they checking the accuracy of the inventory. This process does not indicate the accuracy of the inventory so much as it indicates the problem with users putting in small samples. This exaggerated apparent error also occurs in the vegetation inventory sample clusters, and undervalues the effectiveness of the "Estimation Phase" of the inventory design (where photoestimation gives an initial estimate for stand parameters).

The worst effect, however, is the perception that the inventory is not accurate because of a large difference that may be entirely due to the small sample size chosen to "check" a polygon. If sample sizes within the polygon become very large, the internal sampling error drops to zero, and the remaining error is the real difference between the polygon volume and the volume stated by the inventory. This is the figure which is desired by most people when they ask the question :

What is the actual accuracy of the inventory for a particular polygon ?

Our objective from this WPV field sampling will be to give users a reasonable expectation of the difference they should expect to find when they "check the inventory" in the field, as well as an estimate of the actual error of the adjusted polygon database. In addition, it will establish a sampling protocol for measuring polygon error rates for any other resource values.

What comparison is appropriate - Percent or Actual units ?

In general, percentage is the most desirable way to measure this effect. It is more intuitive for users, and it is simple to understand. The percentage comparisons may change little over time, even when the stand grows - unlike the volume in cubic meters, which changes with the stand. For all these reasons, forest inventory work uses percentage whenever possible.

The only general problem with percentages is for polygons with small averages, where division by zero (or nearly zero) cause the comparison to be invalid or wildly large. If this is a problem, the most promising approach might be to use two strata, one for larger averages and another for smaller ones. In the strata with smaller averages the differences could be stated in actual units. For very small trees, the WPV sampling should not be done at all.

The field work described here will produce the differences in several units and in percentages as well. The design is not dependent on the solution to this issue, and that decision can be made later. Overall, the approach should be concentrated on describing percentage differences in polygon values.

Basis for comparison

The field work will be aimed at describing only a few main parameters. We hope that this will be indicative of other polygon level errors, and expect that it will, because so many of the values are linked together physically. The process can be applied to more parameters if they become interesting enough at a later date. The main measurements are:

Basal Area
Species percentages
Gross Volume
Site Index

These are parameters estimated by the "Phase 1" or "Estimation Phase" of the Vegetation Inventory, and should be good indications of the polygon level variability of the inventory.

Basal Area and Species Percent are of particular interest. This is because these are very easy for users to check in the field, with virtually no training. They are both quick to determine, which allows sufficient plots to be installed in the polygon and therefore to generate fairly good answers. All the determination of stand Basal Area requires is to count trees with a simple angle gauge. The proportion of trees counted, by species, is also the proportion of species by basal area (and virtually the proportion by volume).

In addition, these measurements are well correlated to other issues of volume and value. The error in volume and value for most forest sampling in BC are dominated by the error for these two parameters. Therefore, the analysis should concentrate on basal area and species percent as the standard error rate comparisons. The field work described here will produce values for many measurements which will be of interest. This will provide the data to show that percentage errors based on Basal Area will be a valid guide to errors in other estimated parameters. If the inventory is readjusted in the future (without direct reference to these measurements) then the revised inventory can be evaluated with this same data - there is no need to resample.

Sampling considerations

The stated answer for the polygon, or any corrected value for the polygon, is for the average over the entire polygon, not some "typical" portion. Therefore WPV sampling must cover the entire polygon, with appropriate edge effect measures taken near the polygon boundary. Users, too, are under such an obligation. The process adopted here should be standardized after it is successfully field tested so that a polygon sampling plan can quickly be provided to any users who wish to check a geographic area or some other subset of polygons. We can assume that if such a sampling plan is not made available the users will execute the usual biased selection of plot locations. Then, after the field effort and expense are incurred, they will remain attached to the answer even when it is basically flawed.

The need involved here is for the Resources Inventory Branch be able to produce a sampling plan which the MoF can accept before the field work begins. If they cannot do this quickly and efficiently then differences of field measurements will continually be compounded by sample selection problems. If the user can describe a set of polygons to be checked, the MoF should be able to quickly select specific polygons, and positions within those polygons. It should allow the user to choose the number of plots per polygon, and it should produce maps of both the polygon locations and the points within the polygons.

This process must not become overly expensive. 10-20 polygons for each inventory is sufficient. As the inventory work progresses, there will be plenty of data to support error estimates. Initially, the numbers should be kept smaller until the field procedures are well tested. The total area which is sampled (included in the sorted list) should be recorded by the project manager. This is the weight which should be applied to this data when it is combined with other inventory data.

Selected subsets of the inventory

The "Sampling Error" of the inventory total, as well as the agreement for individual polygons, is for the entire inventory. The answers for selected subsets of polygons are different. This is true whether the subsets are geographically related (a watershed) or related by attribute (all high site Pine on west aspects). Users can expect to find different accuracy for subsets of polygons they chose to check. There is *no way* to anticipate the magnitude of these differences ahead of time. The differences depend critically on how the polygons were selected.

If any valid field check reveals differences which can be adopted into the provincial inventory, that might be an advantage to the Ministry of Forests, and there are several ways to incorporate this information. This process is separate from the WPV sampling, but it emphasizes the need to develop a useful field method and sampling design for this process.

The actual accuracy of those individual polygons might be improved by adjusting the average for that subset, and the process described here would be sufficient to judge the improvement that would occur, as well as the initial accuracy for that subset. If the user expects the entire inventory total to be increased or decreased, based on their sample of a subset, then they will have to sample the entire inventory. If a particular type is checked, and the MoF agrees

that the group should be adjusted, then the values of other polygons in the inventory would have to be adjusted to compensate for this change and conserve the original inventory totals.

When particular polygons are checked (especially ones that are found beforehand to be "suspicious" by field inspection or data inspection) the usefulness of this information is very restricted, virtually to the polygons themselves. Only an actual probability sample over a large percent of the inventory area can be expected to have any large effect on the result.

Other uses of the data

This data will establish a number of items useful for sampling design purposes, such as the number of site index measurements needed, and the relative value of measurements for basal area vs. measurements of tree parameters. These relationship are not well known over the province, since most of the data is from cutting permit cruising on older, higher value stands.

Field Procedures

Polygon Selection

Polygons should be selected by a random or systematic method, proportional to area. The sorted list process currently in place for the Vegetation Inventory is perfectly adequate for this purpose. The sorting criteria are not important, and will be left to the discretion of the project manager. With this selection process the data will be of approximately the same weight in many of the comparisons, and this will simplify the handling and the explanation of the data.

There is no reason to use polygons which have been measured by the Vegetation Inventory, or to avoid them. The selection should be over the entire database.

When access to some sets of polygons is particularly expensive, they could be sampled at a different rate, but the intent during the initial phase of this program is to avoid this process. The selection and weighting mechanics for this process have already been worked out by the MoF for the Net Factoring process, and this method is adequate if access becomes very difficult.

If some polygons cannot be visited because of concerns for expense or safety it is not as important in this project as it is for the Vegetation Inventory. The intent here is to state a reasonable error for the final inventory product, particularly for the larger stem stands, and if none of the WPV data is used during the adjustment process, it does not cause a bias.

Sample Size

Sample size for a polygon is selected to represent one or more days of work. This will vary with access to the area. This is to be decided by the project manager, but the goal should be to have approximately 30-50 plots in the area. It is important to insure a large number of samples in each polygon, not a large number of measurements on a few plots.

For small polygons, the MoF may have to use 100% sampling or 3P sampling. For the present, the attempt should be to use standard inventory plots for this program.

Plot data measured

The data gathered will be limited to timber information This data has a long period of relevance, and is continuous (rather than discrete) data. Other specialty data should be gathered by the appropriate groups, but this basic sampling design would serve their purposes as well.

Top Height should be measured on every third plot, if a suitable tree (by top height definition) is available. If no tree is available, another plot is NOT substituted. This will provide necessary information on the variability of top height, and the changes due to multiple species, etc.

Polygons with trees having an average DBH less than about (initially, 10cm) should not be sampled. The project manager must make this decision. This must be checked in the field, not based on the database values. In case of doubt, do the sample. Stands of very small basal area and small DBH's are of little interest because of the small average to which they would be compared. This criteria of "too small to be sampled" may later be based on tree height, but it would again be the project managers choice.

"Variable plot" sample points should be used if the trees are larger in size, at the discretion of the project manager. Trees down to 4cm at DBH should be measured. An average of 6-8 trees is desired, with no change in BAF during the cruise. Tree counts on each point will provide both basal area and species percentage data.

On measured trees, the diameters and heights should be recorded. Estimation of tree heights is acceptable, provided that accuracy can be maintained (in the opinion of the project manager).

The standard tree measurement data can be gathered on the TD-8 card used by the Vegetation Inventory. The fields for Bark %, log grades, and wildlife codes can be eliminated.

Top height information can be gathered on the TS-10 card. Bark thickness and growth can be eliminated.

Tree Counts vs. Tree Measurements

Most of the variability in this process is with the basal area of the stand. What this means is that the project manager must insure that the crew spends more time doing accurate tree counts, and less in measuring standing trees.

There are two methods of gathering measured trees. One is traditional, and more simple. The second is more efficient and flexible, but newer. The project manager must decide which process to use, but if the newer method can be made effective and routine then there are certainly advantages. The results can be freely mixed from each of these methods. There is no problem

combining the final values for different polygons. The difference is strictly in processing the data.

Method 1: All trees measured. Measure all of the trees on every 4th plot. The plots to measure can be determined ahead of time in 4 patterns, and one of the patterns is randomly chosen by the project planner. This method solves the problem of having every 4th plot in the numbered sequence fall into a poorly distributed pattern within the polygon.

Method 2: The "distributed measure-tree method". The trees to measure are chosen with a large angle gauge. If a 9BAF prism was used to count trees, then a BAF of "X" times larger is used to choose approximately 1/X of the trees during the cruise. If roughly every 5th tree is desired, then a 45BAF gauge would be used. This is most easily done with a Relascope. The exact relationship of one BAF to the other is not important, only a roughly appropriate multiple is needed.

This process distributes the measured trees throughout the stand, and gives increased accuracy to the cruise. I would recommend that a ratio of 1:5 to used initially. For 40 plots, with an average count of 6/plot, this would be roughly 240/5 = 48 trees. The exact number of trees will be variable, just as it is with the usual method of variable plot sampling.

With both of these methods, the process of insuring that at least one tree of each species is measured should be followed, just as in the Vegetation Inventory and in standard cruising practice. I would suggest that the first tree of any species is measured, and if another one is selected during the cruise then that "insurance tree" would be dropped from the computation.

Sample distribution

A grid pattern should be used for the installation of plots. If the grid pattern proves to be too difficult in practice then lines of plots can be adopted later, but this becomes more complicated in both the analysis and applicability to users, and should be avoided in the initial stages of the program. The assumption is that users will also check the data by using a grid pattern.

The starting point for the grid should be randomly chosen in a rectangle which surrounds the entire polygon. An initial point should be chosen inside the rectangle, and if it is within the polygon it will be the starting point for the grid - otherwise random numbers should be chosen until one falls within the polygon and will serve as the starting point. A grid which will approximately give the sample size desired should then be applied, and when this results in slightly more or fewer plots then that is acceptable, providing that the sample can still be done in whole day increments.

Anticipated Field problems

Large or complex shaped polygons

Where necessary (and this should be a rare situation) large or complex polygons can be divided. When the polygon is chosen by the selection process, and the decision is made to divide it, lines which can be reliably located in the field are used to divide the original polygon into several smaller polygons. It is not necessary that these have exactly the same area, but it is desirable that the smaller polygons are roughly the same size. Random positions in a square covering the entire original polygon should then be chosen, and when one of these falls into one of the smaller polygons then that polygon is selected for WPV sampling. This insures that the parts are chosen proportional to their area (without having to measure it).

This polygon division is *not a desirable process*, because the results now indicate the accuracy for the partial polygon, not the full one. However, if it is operationally necessary, this seems to be the best compromise procedure.

Plots that cannot be installed

There will be some cases where, for safety reasons, plots cannot be installed. The procedure for this should be basically the same as with Vegetation Inventory plots. A plot location with similar characteristics (in basal area, site index and species mix) should be chosen, and substituted for the original plot.

Time and effort are miscalculated by the project planner

If the measurements are completed well before the expected completion date then the crew should take the time to scout future locations, do quality control, or to otherwise occupy their time. Extra plots should not be installed.

The only possible additional work on that polygon would be to take additional measurements on already established plots or trees (selected randomly). Choosing plots which happen to be convenient is not acceptable.

If the series of plots is not completed, then the area will have to be revisited. Since this is the case, the number of plots selected should be slightly conservative, or the workday should be flexible.